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ALTGELD HALL STACKS

BUREAU OF SHIPS

MANUAL

CHAPTER 50

AUXILIARY STEAM TURBINES

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U. S. NAVY DEPARTMENT

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ALFRED HALL STA

BUREAU OF SHIPS MANUAL

CHAPTER 50

AUXILIARY STEAM TURBINES

NAVY DEPARTMENT,
Bureau of Ships,
20 December 1946.

This chapter is a revision of Bureau of Ships Manual, Chapter 50, "Auxiliary Engines," dated 25 February 1944.

This revised chapter becomes effective upon receipt and shall be inserted in its proper place in the Manual Binder.

E. W. MILLS,
Vice Admiral, U. S. N.,
Chief of Bureau.

Approved:
JAMES FORRESTAL,
Secretary of the Navy.

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Chapter 50

AUXILIARY STEAM TURBINES

SECTION I—AUXILIARY STEAM TURBINES

50-1. SCOPE OF INSTRUCTIONS RELATIVE TO TURBINES

The auxiliary steam turbine installations on board ship in the Navy vary to such an extent that detailed operating instructions for each type cannot be covered in this manual; general principles only will be given. The manufacturer of the driven auxiliary issues detailed instruction pamphlets for the individual installations. These instructions should be studied in conjunction with the instructions contained in this chapter of the manual in order that the highest efficiency may be effected in the operation of the units. If any conflict exists between the instructions as laid down in this chapter and the manufacturer's instructions, the Bureau should be consulted.

50-2. TURBINE CLASSIFICATION

(1) In general, auxiliary turbines in naval service may be classified as follows:

(*a*) Speed; constant or variable.

(*b*) Exhaust conditions; condensing or noncondensing.

(*c*) Position; shaft horizontal, vertical, or inclined.

(*d*) Type; impulse or reaction, or a combination of impulse and reaction.

(*e*) Direction of steam flow; axial, radial, or tangential re-entry (helical).

(*f*) Stages; single or multiple.

(*g*) Drive; direct or geared.

(*h*) Service; based upon driven auxiliary.

(*i*) Classification by power output capacity, limiting speeds, etc.

(2) Auxiliary turbines are ordinarily of the impulse, radial, helical or axial flow single-stage type, except electric generator turbines, and operate against a back pressure of 10 or 15 p. s. i. gage depending upon the auxiliary exhaust line pressure of the vessel in which installed. On the later destroyers, cruisers, aircraft carriers, and battleships, auxiliary turbines operate against a back pressure of 15 p. s. i. gage.

(3) Turbines for driving electric generators are ordinarily of the impulse, axial-flow, multiple-stage, geared type and operate condensing. Impulse turbines are of the Curtis-Rateau or straight Rateau type.

50-3. STARTING AUXILIARY TURBINES

When a turbine is first put into service, it is subject to variable expansion due to changing conditions of load and the consequent changes in internal pressure and temperature. The foundation structure is also subject to seasoning and requires time to accommodate itself to service conditions. Therefore, a reasonable length of time should be spent in warming up the turbine, gradually bringing it up to speed and applying its load. No definite time is specified herein for performing these operations, as this depends upon the individual machine. If the instructions of the turbine manufacturer and those given herein are carefully observed, successful operation will result. The steps in starting a noncondensing auxiliary steam turbine are as follows:

(*a*) Be sure that turbine is free of all foreign matter such as tools, covers, etc. Be sure that all working parts are clean and well oiled. Test the relief valve and other safety devices by hand where practicable.

(*b*) Ascertain the level of oil in reservoir. The level should be approximately at the maximum mark on the gage to allow for the drop in level due to the oil which fills the system when the pump is started.

(*c*) Turn the unit by hand where practicable using strap wrench or other suitable means. It should revolve easily and without noise or grinding of any kind.

(*d*) If a stop valve is provided in the exhaust line, be sure the valve is open before steam inlet valves are touched. If the exhaust valve is of the spring loaded type, it is not to be opened at this time.

(*e*) Drain the turbine casing and the branch line from the auxiliary steam line to the turbine throttle. This shall be carefully and thoroughly done. The branch line between turbine throttle and stop valve may contain water, especially if there are leaky valves; therefore, this line should be drained before opening the stop valve. If the branch line is not fitted with a drain, open the turbine throttle and allow the water to drain into the turbine casing and out through the turbine drains. Then crack the stop valve until steam shows in the turbine drains. A sudden and large opening of the stop valve may

result in damage from water hammer and may cause injury to personnel.

(*f*) Close the throttle valve and open the stop valve.

(*g*) See that pump pressure regulating valve in steam line, if provided, is in operating condition. See that the driven auxiliary is in proper condition.

(*h*) Crack the steam inlet valve and spin the rotor. Check oil pressure gage and sight flows to see that bearings are getting oil, or, with oil ring lubrication, where bearing caps are fitted with inspection openings, see that the rings are revolving. There should be no sound of rubbing of the gland packing or rotor. Watch the exhaust pressure gage; if the exhaust pressure is excessive, shut down the turbine immediately and remedy the trouble before attempting to start it again. If the exhaust pressure is satisfactory, run the turbine slowly for several minutes; if normal conditions prevail, gradually bring the turbine up to approximately normal speed. During this warming and accelerating period listen carefully for any rubbing, unusual noise, or vibration. If any rubbing is detected, decrease speed until all evidence of it has disappeared. If noise continues, secure the unit immediately and notify the engineer officer. Do not resume operation until the cause of the trouble has been determined and corrected. Also during the warming up period see that the driven auxiliary is functioning properly.

(*i*) Close the turbine drains.

(*j*) The latest practice is to provide spring loaded exhaust valves in the exhaust lines of noncondensing steam turbines. These valves, while capable of being opened full or seated by hand, cannot be positively closed by hand and are designed to open automatically when the steam pressure in the turbine casing exceeds the pressure in the exhaust line by approximately 2 p. s. i. If provided, the spring loaded exhaust valve shall be opened full by hand when the turbine has reached approximately normal operating speed.

(*k*) If the unit is fitted with an emergency overspeed trip, the system shall be operated by hand after approximately normal operating speed is reached. Make sure the trip valve closes. If the overspeed trip mechanism does not function properly, the unit shall not be used until the trouble is rectified except in cases of extreme emergency.

(*l*) Having demonstrated that the tripping mechanism functions properly, reset the latch and bring the unit to the required speed by proper adjustment of throttle or governor. Give the unit a thorough trial under load conditions before leaving it, paying special attention to lubrication and governor action.

50–4. OPERATION OF AUXILIARY TURBINES

The following observations should be made during operation of an auxiliary turbine.

(*a*) On more recent vessels external oil coolers are incorporated. On such units the temperature of oil leaving the bearings should be observed and the oil cooler should be bypassed, if practicable, until the oil discharge temperature reaches 100° F. Thereafter the oil temperature should be controlled by regulating the flow of cooling water.

(*b*) Observe the oil level in the reservoir to be sure that it has not dropped below the normal level, especially when starting the first time after filling. Apply oil daily to governor oil-feed cups and connections between levers of the governing mechanism.

(*c*) Watch the oil temperature; it should normally be about 150° F. when leaving bearings. Under no circumstances should the maximum oil temperature be allowed to exceed 180° F. The maximum allowable temperature rise of oil passing through any bearing is 50° F. Low temperatures under normal operating conditions should be avoided since the high velocity of excess cooling water through the cooler and pipe lines will cause erosion, thereby reducing the life of this equipment.

(*d*) It is current practice to allow only one hand-operated nozzle valve on auxiliary turbines; this is to permit normal full load to be carried with low steam pressure or high back pressure, or to permit an overload to be carried with normal steam conditions. However, many of the older auxiliary turbines are equipped with several hand-operated nozzle valves which may be opened or closed as load and steam conditions require. When a nozzle is cut in, it must be opened wide in order to avoid wire-drawing the steam, which is inefficient and also scores the nozzles and valves. For example, it is much more economical to operate with one nozzle wide open than it is with two nozzles partly open. Furthermore, to obtain best economy, a turbine should be run with as few nozzles in use as will give the required power when the throttle is as nearly as possible wide open. For turbines with several hand-operated nozzle valves, small changes in output should be accomplished with the throttle, but large changes should be made by cutting nozzles in or out; i. e., always carry, as nearly as possible, full steam pressure in the chest.

NOTE.—Westinghouse propeller-type forced draft blower turbines, fitted with remote nozzle control gear, are designed for throttling the nozzle valves, if desired, and in this case manufacturer's instruction pamphlets may be followed.

(*e*) Watch for oil, steam, and water seepages and correct if found. The exterior should be kept free from dust, dirt, oil, and water.

(*f*) If a metal edge filter (Cuno or similar types) is provided in the oil line, the filter cleaning handle should be turned at least once each watch.

50–5. SECURING AUXILIARY TURBINES

The steps for securing an auxiliary turbine are as follows:

(*a*) Reduce the load.

(*b*) Close all hand nozzle valves.

(*c*) Trip the overspeed trip, if provided, to slow down the turbine. Close the throttle valve.

(*d*) Close exhaust valve.

(*e*) Close lubricating oil cooling water valves.

(*f*) Open drain valves.

(*g*) After all condensate has drained and turbine casing has cooled to engine room temperature, close the drain valves.

(*h*) When the turbine is shut down, if only for a short time, take precautions to guard against steam bleeding into the turbine casing in order to prevent corrosion of internal parts.

50-6. STARTING TURBINES DRIVING ELECTRIC GENERATORS

To start a turbine driving an electric generator proceed as follows:

(*a*) Be sure that turbine is free of all loose material, and that all working parts are clean and well oiled. Test all safety devices where practicable. Trip the overspeed mechanism by hand to insure proper functioning.

(*b*) Ascertain that the temperature of oil in the reservoir is at least 60° F. (See art. 50-7.) The level of oil in the reservoir should be approximately at the maximum mark on the oil level gage.

(*c*) Check the axial setting of the rotating element by means of the rotor position indicator or micrometer, if provided. Log the axial position of the rotor as measured and specify that this is a cold reading.

(*d*) Turn unit over by hand if a strap wrench is provided for this purpose. It should revolve easily and without noise or grinding of any kind.

(*e*) Check to see that the overspeed tripping mechanism is properly set.

(*f*) Open the drain ahead of the throttle valve before opening stop valve. It is necessary to drain the steam line to throttle valve before opening throttle valve in order to prevent damage from water hammer.

(*g*) Open the stop valve ahead of the throttle valve slowly so as to warm the piping gradually, and drain away the condensate.

(*h*) See that all turbine drain valves are open.

(*i*) See that exhaust valve, if fitted, is open.

(*j*) Put the dynamo condenser into service and bring up the vacuum to about 15 inches of mercury.

(*k*) Start the hand oil pump and pump oil to bearings, keeping hand oil pump turning until the attached pump takes charge. Check pressure gages and sight flows to see that all bearings are receiving oil. On some generator turbines pressure from the hand oil pump lifts the controlling valve and steam cannot be admitted to the unit until the governor gear is actuated by the hand pump oil pressure. On other units the controlling valve must be jacked by means of a special lever when starting. After the controlling valve has been opened by hand oil pumps or jacking lever, open the throttle valve sufficiently to start the rotor spinning. Under no circumstances shall steam be allowed to enter the turbine for any length of time with rotor standing idle as this will distort the rotor by uneven heating, and will possibly cause vibration when the turbine is running. After the rotor has started revolving, trip the throttle valve by hand immediately to see that the tripping mechanism operates properly.

(*l*) Reset the overspeed trip, raise controlling valve, and open throttle valve again sufficiently to keep the rotor turning slowly.

(*m*) Admit steam to shaft packings.

(*n*) By means of the throttle valve, slowly bring the rotor up to about half speed and run at that speed for several minutes to warm up the casing and rotor. See that there is no indication of rubbing of the shaft packing or rotor. The length of this warming period varies with individual machines; consult manufacturer's instruction pamphlet for recommended warming period.

NOTE.—When starting a generator turbine after a short shut down, the turbine may not come up to speed as smoothly as when starting cold because of temporary distortion of the rotor caused by uneven cooling. In this case the rolling period should be prolonged until the rotor straightens out and the unit runs smoothly.

(o) During the warming period watch all bearing oil temperatures and listen carefully for any rubbing, unusual noise, or vibration. If any rubbing is detected, decrease speed until all evidence of rubbing has disappeared. If noise continues, secure the unit immediately and notify the engineer officer. Do not resume operation until the cause of the trouble has been determined and corrected. A rubbing noise may indicate either a lack of axial clearance in one direction, or packing rub on the shaft. The rotor position should be shifted by changing thickness of thrust bearing liner if the axial clearance is incorrect. If the packing rubs, examine it and refit.

(*p*) When the temperature of the oil leaving the bearings reaches about 100° F., start the circulation of water in the oil cooler, regulating the flow of cooling water to suit conditions.

(*q*) Close turbine drain valves and increase the vacuum as much as conditions will permit.

(*r*) When the turbine is satisfactorily warmed up, bring the unit up to operating speed.

(*s*) Accelerate rapidly through the critical speed. The slight vibration which may occur when going through critical speed should disappear as soon as the critical speed has been passed. The critical r. p. m. of turbine may be determined from the manufacturer's instruction book or from plans and is usually 20 to 25 percent below normal operating speed for a generator turbine. All other auxiliary turbines have the critical speed well above the operating range.

50–7. OIL TEMPERATURES WHEN STARTING

The following points shall be observed in connection with oil temperatures when starting a generator turbine:

(*a*) Units shall not be started until the oil in the reservoir is at least 60° F. Oil below 60° F. shall be removed from the reservoir and heated in the settling tank between 60° and 90° F. before the unit is turned over.

(*b*) When starting up with oil in reservoir between 60° F. and 100° F., the unit shall be operated slowly until such time as the inlet oil to bearings is 100° F., or until such time as there is a free flow of oil from the bearings, at which point full speed may be obtained and load applied.

(*c*) Due caution shall be used when starting with cold oil; lower temperatures require lower warming-up speeds.

(*d*) Operating temperatures of 100° F. to 130° F. to the bearings should be obtained soon after full speed is reached.

For general information relating to oils and lubrication, refer to chapter 45 of this manual.

50–8. OPERATION OF GENERATOR TURBINES

The following steps should be observed during operation of a turbine:

(*a*) See that water is circulating in the oil cooler.

(*b*) When the unit is operating properly under control of the governor, put the generator on the line in accordance with chapter 61 and instructions issued by the generator manufacturer. In the case of an alternating current machine, it will be necessary to synchronize the generator by means of the synchronizing device provided on the turbine.

(*c*) See that the oil pump delivers an ample supply of oil to the bearings and to the hydraulic cylinder. The oil level must be kept between the limits on the oil level gage.

(*d*) At regular intervals determine the temperature of the bearings. A fair running temperature of the return oil is about 150° F. Under no condition should the maximum temperature exceed 180° F. The maximum temperature rise of oil passing through any bearing should not exceed 50° F. A log should be kept of bearing oil temperatures and pressures.

(*e*) The axial position of the turbine rotor should be recorded where a micrometer for measuring this clearance is provided. When comparing readings to determine thrust bearing wear, be sure to compare readings obtained under the same conditions of operation.

(*f*) Adjust valves in gland-sealing steam lines as required. A pressure of between ½ and 2 p. s. i. gage should be sufficient for maintaining the proper vacuum.

(*g*) Inspect all oil-feed valves, sight flows, and the complete oiling system, making sure that all parts are working properly.

(*h*) Check the vacuum to see that the condenser is operating properly.

(*i*) Check for leakage of steam, water, or oil.

(*j*) Check for smoothness of operation and freedom from unusual noise.

(*k*) Check for correct designed operating conditions by taking readings of steam and oil pressure gages.

(*l*) Check for proper circulation of oil and water in cooler.

(*m*) Once a watch, when load conditions permit, partially close the throttle valve to make sure that the valve stem moves freely through its packings.

(*n*) Do not keep the turbine in service unless it is known that the safety devices are in condition to operate, except in extreme emergencies.

(*o*) A visual inspection of the tooth contact of the pinion and gear, and oil spray nozzles thereto, should be made periodically, at the discretion of the engineer officer. An inspection cover located over the gear mesh is sometimes provided for this purpose.

(*p*) The oil strainer baskets in use should be inspected once each watch and more frequently on new installations. They should be cleaned frequently by switching oil flow to other basket. If steel particles are attached to the magnets, inspect the gears for lack of oil. If particles of babbitt are found in the screen, inspect the bearings.

(*q*) Some generator turbines are provided with one or more hand nozzle valves. These valves may be opened or closed as steam conditions require. However, *they shall always be either fully closed or fully open.*

50–9. SECURING GENERATOR TURBINES

The steps to secure a generator turbine are as follows:

(*a*) Shift the load to another machine by reducing the load on the generator. Trip the generator circuit breakers in accordance with the instructions in chapter 61.

(*b*) Close the throttle valve by striking the overspeed tripping mechanism trip latch.

(*c*) Always operate the hand oil pump until rotor stops revolving in order to avoid unnecessary bearing wear.

(*d*) Shut off the steam supply to packing.

(*e*) Shut off the water to oil coolers.

(*f*) Close the stop valve ahead of the throttle valve and open the drain ahead of the throttle valve to relieve pressure and drain the line.

(*g*) Open throttle valve, turbine casing, and steam-seal line drains.

(*h*) Operate the air ejector for several minutes to draw out all vapor and water from the turbine in order to prevent internal corrosion.

(*i*) After all condensate has run out and casing has cooled to engine room temperature, close all drains and secure the exhaust valve, if provided.

(*j*) When the turbine is shut down for any reason,

even though for only a short period of time, take every precaution to guard against steam bleeding into the turbine casing, in order to prevent corrosion of internal parts.

(*k*) If the turbine is shut down for any reason, even though for only a short period of time, the unit must be brought up to speed with the same care that is exercised when starting the turbine cold.

50–10. LUBRICATION OF BEARINGS

(1) As steam turbines run at high speed, it is absolutely essential that all bearings receive the proper amount of lubrication. In addition to the pressure caused by the rotation of the moving parts, provision must be made for the additional strain thrown on the bearings when the ship rolls and pitches. On a ship rolling or pitching excessively the additional force applied to the bearings due to gyroscopic action is enormous. Therefore, the importance of using the proper oil, maintaining this oil at the proper pressure, and keeping turbine bearings in adjustment at all times cannot be overemphasized.

(2) *Oil grooves.* The grooving of the bearings and the maintenance of the proper oil pressures have an important relation to the oil supply for both cooling and lubrication. Oil grooves in bearings shall not be cut in any other way than as shown on plans.

50–11. SELECTION OF LUBRICATION OIL

Navy symbol number 2190T oil, having a viscosity of 185–205 S. S. U. at 130° F., should be used for the lubrication of all auxiliary turbines and reduction gears, except in the case of turbine-driven, worm-gear speed reducers. Navy symbol numbers 3080 oil having a viscosity of 75–90 S. S. U. at 210° F. should be used for the lubrication of turbine-driven, worm-gear speed reducers.

50–12. CARE AND OPERATION OF THE OIL SYSTEM

(1) The use of clean, pure oil is essential to long life and successful operation of a turbine, and every possible measure should be taken to keep the oil in good condition and to guard against the admission of water, dirt, and other foreign substances to the system.

(2) On turbines having pressure lubrication, an oil strainer or filter is generally provided in the oil line on the discharge side of the oil pump. This filter is usually of the metal edge type (Cuno or similar type) on all machines except generator turbines. The metal edge type filter should be cleaned at least once each watch by giving the handle a complete turn or two. At periodic interview the filter should be dismantled and cleaned with kerosene or other approved cleaning fluid. With the duplex type of magnetic strainer employed on generator turbines, only one basket is in use at a time, and the basket not in use can be removed for cleaning while the machine is in operation. The strainer baskets should be cleaned at regular intervals, care being taken to remove any metallic particles that may adhere to the magnets in the strainer baskets.

50–13. OIL RELIEF VALVES

A relief valve is usually fitted in the lubricating system to avoid excessive pressures and the manufacturer's special operating instructions should be followed. In most turbines the oil relief valve is set for about 10 p. s. i. gage when operating at normal speeds. However, if it is found that the setting allows oil to leak from the ends of the bearing and be thrown about the machinery spaces, the pressure setting may be slightly reduced to allow some of the oil to be bypassed back into the oil reservoir. Where excessive pressures exist, this may result in the gravity return of the oil back to the reservoir not being rapid enough to prevent the throwing of oil. Clogged drain holes have the same effect.

50–14. OIL PRESSURE

When a turbine is started, the gage on the oil line of pressure-lubricated machines should be carefully watched to note that the oil pressure builds up. When the machine has reached normal speed and the oil has become warm, the pressure should be checked against the normal pressure for the speed, as stated in the manufacturer's pamphlet. While the turbine is in operation, the gage should be read frequently to determine that the proper pressure is being maintained.

50–15. FAILURE OF OIL SUPPLY

(1) If the supply of oil to the bearings is interrupted, stop the turbine immediately. Take such steps as are necessary to get the oil circulation reestablished. These steps may include any one or a combination of the following:

(*a*) Clean strainers.
(*b*) Repair broken line.
(*c*) Remove obstruction from line.
(*d*) Put additional oil in the reservoir.
(*e*) See that the proper valves are open.
(*f*) Increase oil pressure by increasing the setting of oil relief valve.

(2) If a turbine has to be shut down due to an overheated bearing, it should be slowed down, but kept turning over at a low speed until the bearings and journal have cooled sufficiently. Otherwise the bearing metal will freeze to the shaft and make repairs much more difficult.

50–16. LARGE LOSS OF OIL

If it is noticed that the oil supply is failing, immediately examine all bearings, lines, and reservoir to discover the leak. Replenish the oil supply in the reservoir. If the reservoir is damaged, make temporary repairs to prevent loss of oil, or secure the turbine in case temporary repairs are impracticable.

50–17. OIL LEAKAGE

There are various contributing causes for leakage and for throwing of oil by turbines. The majority

of these causes may be remedied by the operating personnel. The following instances are cited with corrective measures taken:

(*a*) If oil leakage occurs where a shaft emerges from a housing, the oil seals or deflector may be excessively worn or damaged. In such a case the oil seal or deflector should be replaced.

(*b*) The drain holes in bearings may be too small or become clogged with dirt or residue in the oil. The drain holes are usually designed by the manufacturer to take care of the original bearing clearance, and as the bearings wear and the drain holes become clogged with dirt, there is a tendency for a greater quantity of oil to pass through the bearings than the drain holes can accommodate. This causes the oil to back up and out at the ends of the bearing. The holes may be reamed out to a slightly larger diameter, and it may be found advisable to widen the oil grooves slightly. There is a limit to the size to which these holes may be safely enlarged; if the bearings are badly worn, the only remedy is to fit spare bearings. The passage of the oil grooves and the drain holes should be cleared of all sediment when the bearings are taken down for overhaul.

(*c*) Leakage from ends of bearings may be caused by setting the oil relief valve too high. (See art. 50–13.)

50–18. REBABBITTING BEARINGS

Practically all of the high-speed bearings used on turbines in the Navy are of the babbitt-lined, split sleeve type. Designed oil clearances for turbine bearings are generally shown on plans, but where these are not available, it is recommended that the limits given in table titled "Oil Clearances for Turbine, Reduction Gear, Generator, and Motor Bearings," of chapter 40 be adopted. The figures in this table are merely a guide, and bearings shall be rebabbitted before the maximum listed is reached when undue vibration or other abnormal operating conditions are present. When designed bearing clearances differ from those listed in this table and no rebabbitting instructions are available from instruction books, the following procedure is recommended:

(*a*) When designed clearance is equal to or in excess of values listed in table referenced above, rebabbitt only when wear exceeds original clearance by 0.005 inch.

50–19. THIN SHELL BEARINGS

On some of the later high-speed turbines in the Navy, bearings of the "thin shell" type are employed. In this type of bearing the babbitt thickness is ⅛ inch or less. Such a thin layer of white metal permits more rapid dissipation of heat than occurs in the conventional type of bearing. These thin shell bearings cannot be rebabbitted with tender or shipyard facilities. Therefore, when clearance becomes excessive in thin shell bearings, they are to be replaced and not rebabbitted.

50–20. THRUST BEARINGS; TYPES

Thrust bearings are provided in turbines for maintaining the axial position of the rotor and for absorbing thrust. Thrust bearings used are of three types, as follows:

(1) Ball thrusts.
(2) Nonsegmental or tapered land thrusts.
(3) Pivoted segmental thrusts.

50–21. BALL THRUST BEARINGS

Ball thrust bearings are used in turbines which run at a relatively slow speed or where the thrust load is relatively light. These bearings are generally of the angular contact or so-called "deep groove" type of either single or double row mounting and take axial load only. Clearance is provided between periphery of outer race and the housing to assure that no radial load will be taken. In certain cases where the thrust load is extremely light and space limitations require it, ball bearings are used which take both axial and radial load. In cases where a ball bearing is provided for taking thrust only, it shall have a radial clearance. Ball bearings are mounted on turbine shafts with light press fits as defined in appendix 1 of Navy Department Specification 42B5. When inspecting ball thrusts for any reason, be sure that the outer races are secured axially. However, outer races of radial bearings should be free to float axially in their housings in order to adjust themselves to linear expansion.

50–22. NONSEGMENTAL THRUST BEARINGS

The nonsegmental type thrust bearing consists of a thrust collar keyed and secured to the shaft by means of lock nuts or other devices, and two babbitt-faced thrust plates between which the collar rotates. In some turbines one end of a journal bearing is faced with babbitt and serves as a thrust plate. In still other turbines two collars are secured on the shaft, one at each end of a journal bearing, and each end of the journal bearing is provided with a vertical babbitted face which serves as a thrust plate. Turbines manufactured by the General Electric Company for driving generators are equipped with nonsegmental type thrust bearings known as "tapered land" thrust bearings. In this type of thrust bearing the stationary surfaces on the side that absorbs the thrust is a solid ring with a babbitted surface. A series of about six radial grooves are cut in the babbitt for distribution of oil. Each babbitted surface between the radial oil grooves is machine tapered in both circumferential and radial directions to provide a wedge shaped oil film. The inactive stationary thrust surface is not tapered. With proper lubrication the lands of collar thrust bearings should experience little or no wear and the designed end play will change very little with service. Shims are generally provided between the thrust plates and their housings, and if end play adjustment is necessary, this may be accomplished within reasonable limits by changing the thickness of the

shims. In later tapered land type bearings the entire bearing is arranged to pivot on a yoke and holding plate located at the end of the bearing assembly. When nonsegmental thrusts are dismantled for inspection, the grooves in the thrust plates for distribution of oil over the thrust surfaces should be carefully cleaned of all dirt and sediment to assure free flow of oil.

50-23. KINGSBURY THRUST BEARING

The thrust bearing most used in naval turbines is of the pivoted segmental type as manufactured by Kingsbury. The Kingsbury thrust in its simplest form consists of several pivoted segments or shoes, and a revolving thrust collar secured to the shaft. The shoes and collar, encased in a housing, are immersed in oil. The principle of operation of this thrust bearing is that when one flat surface is moved along another, the two surfaces, when free to do so, assume an inclined position and become separated by a thin wedge-shaped film of oil. The collar is made of forged steel and the thickness is kept uniform all around. Great care is taken to make the working surfaces flat and smooth, and at right angles with the shaft. The marks left by final machining or grinding are removed by lapping. The shoes are faced with babbitt and the bearing surfaces are machined and then scraped to an accurate surface plate. Little trouble should be experienced in the operation of Kingsbury bearings. However, it is essential that the oil be clean and free from grit, water, and other impurities. If adjustment of end play is necessary, this may be accomplished within reasonable limits by changing the thickness of shims which are usually provided between the base ring or leveling plate and the thrust bearing end cover.

50-24. CARE OF BEARING SURFACES

If the babbitted thrust faces of thrust plates or shoes of a bearing become bruised, the bruises should be removed by scraping the faces to an accurate surface plate. However, in the case of tapered land thrust bearings of General Electric manufacture, the tapered land thrust plate must be scraped by means of a special fixture provided. For a description and directions for use of the special fixture, the manufacturer's instruction pamphlet should be consulted. Slight rusting of the collar faces may be removed with a fine oil stone. If deep rusting occurs, refinishing will be necessary. Never use a coarse-grained stone, a scraper, or a file on the collar faces.

50-25. THRUST BEARING END PLAY

The end play for turbine thrust bearings of the collar or pivoted segmental type is generally listed on the plans or in the instruction book. When the end play is checked, the result should be compared with the manufacturer's recommendation. The normal operating end play of auxiliary turbine thrust bearings is about 0.010 inch to 0.015 inch. The simplest method of checking end play is by moving the rotor to one extreme axial position and then to the other with shoes in place, measuring the travel by means of an indicator. On turbines driving through single helical gears the rotors may be shifted to extreme axial positions by merely turning the shaft in one direction and then in the other direction.

50-26. TYPES OF GOVERNORS

(1) All auxiliary turbines in Naval Service are equipped with governors of either the speed-limiting or constant speed (speed regulating) type. Operating personnel should be familiar with the type of governor installed on each turbine and ascertain that such governors are properly set, tested, and kept in operating condition.

(2) A speed-limiting governor is defined by the General Specifications for Machinery as a governor, which, by control of the steam admission to a turbine, will not permit the turbine to operate at a speed in excess of that to which the governor is adjusted, but will permit the turbine to continue in operation at this speed. It is fundamentally a safety device, the required speed regulation being obtained by manual control, pressure regulating governor or other means. This type of governor, being adjusted to the maximum operating speed of the turbine, has no control of the steam admission to the turbine until this speed is approached, regardless of load, exhaust, or other condition. Speed-limiting governors are generally of the centrifugal, direct-acting type. An exception to this type is found on some turbines where the steam regulating valve is hydraulically operated but the oil pressure is controlled by a centrifugal governor. An exception exists also in the Westinghouse propeller type forced draft blowers. With this type, the governor is actuated by oil from an impeller type pump mounted on the turbine shaft. The speed regulation of speed-limiting governors from specified overload to no load shall not exceed 5 percent of the speed setting. For turbine driven centrifugal pumps (not propeller type) the "no-load" condition, as regards speed regulation, is considered as the lowest load attainable with the pump operated at shut-off condition; i. e., with the discharge valve closed. Under any condition of operation, including loss of pump suction, the speed-limiting governor shall limit the speed of the turbine to 110 percent of maximum designed speed. Speed-limiting governors are provided on turbines for driving all types of pumps, and all forced draft blowers. A speed-limiting governor shall never be lashed down or otherwise rendered inoperative.

(3) A constant speed (speed-regulating) governor is defined by the General Specifications for Machinery as a governor which, by its control and regulation of the steam admission to a turbine, automatically maintains the speed of the turbine at a predetermined rate, under all conditions of load and exhaust pressure, within the limits of design of the turbine. Governors of this class are either

of the centrifugal, direct-acting type, or of the hydraulic relay type centrifugally controlled, using lubricating oil as the relaying medium for the actuating force. Turbines for driving air compressors and small turbo-generators are usually equipped with constant-speed governors of the centrifugal direct-acting type. Large generator turbines are usually equipped with constant-speed governors of the hydraulic relay type. Speed-regulating governors on air-compressor and small generator turbines shall be kept in such condition that they will maintain the speed of the turbine within 5 percent of the normal operating speed under all conditions of load from full load to no load. The speed-regulating governors on generator turbines shall be kept in such condition that the speed regulation, however momentary, shall not exceed 5 percent of the designed normal operating speed of the turbine between the "no load" and "full load" conditions, when the load is applied or removed suddenly.

50–27. OVERSPEED TRIPS

To insure that they will not run at speeds greater than that for which they are designed, turbines equipped with constant-speed (speed-regulating) governors are also fitted with overspeed trips which shut off steam to the unit after a predetermined speed has been reached. This predetermined speed is about 110 percent of normal operating speed. Overspeed trips shall never be lashed down nor otherwise rendered inoperative.

50–28. TEST OF OVERSPEED TRIPS AND SPEED-LIMITING GOVERNORS

(1) Overspeed trips shall be tested by hand as prescribed in articles 50–3 (l) and 50–6 (k) every time a turbine is put into operation after having been secured. This test is not a requirement when a turbine has been temporarily secured during maneuvers, target practice, etc.

(2) Overspeed trips are installed primarily for the protection of operating personnel and great care must be exercised in their testing and maintenance. In addition to being tested by hand, overspeed trips in use should be tested each week by actually overspeeding the units, where practicable. Also, overspeed trips should be tested by overspeeding the units prior to being put in service after an idle period of one week or more. In making the overspeed trip test, start the turbine and run it slowly until adequately warmed up. Then with the constant-speed (speed-regulating) governor rendered inoperative, gradually increase the speed of the turbine until the tripping speed is reached. The test is made under the supervision of the engineer officer, and with a reliable man at the turbine throttle and a man with a tachometer at the exposed end of the shaft. The trip should function when the speed is about 10 percent above the normal operating speed. If the overspeed trip fails to function at this speed, the operator at the throttle shall trip the unit by hand. Necessary adjustment shall be made and the test repeated until satisfactory performance is obtained. The result shall be entered in the engine room log. A turbine shall not be used if the governing mechanism cannot be adjusted to hold the turbine within the prescribed speed, except in an extreme emergency and after obtaining permission from the officer in charge.

(3) (*a*) Once a quarter, and at such other times as may be considered necessary, speed-limiting governors shall be tested by speeding up the turbines by an approved method (see method below) and the result entered in the engine room log.

(*b*) The speed-limiting governor test shall be conducted under the supervision of the engineer officer, with a reliable man stationed at the turbine throttle and a man with a tachometer stationed at the exposed end of the shaft.

(*c*) To make the speed-limiting governor test, start the turbine and run it slowly until it is adequately warmed up. Then open the throttle and gradually increase the speed, taking readings with a tachometer. As the turbine approaches full speed, observe the action of the governor. The governor should come into action smoothly and operate the governor valve to control the speed. When the governor apparently has control, carefully open the throttle valve somewhat wider and make sure that the speed does not increase to more than 5 percent above the maximum operating speed. If the governor fails to function at the proper speed, the necessary adjustments should be made according to directions as set forth in the manufacturer's instruction pamphlet. Usually this is accomplished by changing the tension of the external spring by means of an adjusting nut. If a speed-limiting governor is dismantled for any reason, a test shall be conducted to assure proper functioning of the governor before the unit is put back into service.

50–29. GLAND PACKING

Packing is fitted around the shafts of all turbines to prevent leakage of steam from, or ingress of air into, the turbines under all conditions of operation, warming up or standing by. Proper functioning of shaft packing is essential to obtain efficient operation from a turbine. The shaft packing used in auxiliary turbines in the Navy consists of carbon rings for noncondensing turbines and usually a combination of carbon rings and labyrinth for condensing turbines. Each packing box of a noncondensing turbine generally has a cavity between the outer ring cell and the next inner ring cell which is tapped for connecting to a drain line. Never install a valve or shutoff of any kind in the drain lines from packing glands of a noncondensing turbine. These drains should always be free to exhaust at atmospheric pressure. Turbines which normally operate condensing have steam-sealed glands arranged with an inner and outer section, with provision for a steam connection to the space between the sections. Steam is led to the glands from an external source at a pressure

slightly greater than that of the atmosphere, generally 1 or 2 p. s. i. gage, for sealing of glands when turbine is running under a light load. The high pressure gland leakoff is piped to the low pressure gland which is always under a vacuum. At higher loads the steam leakage from the high pressure gland is sufficient to seal the low pressure gland and no sealing steam from an external source is required.

50–30. CARE OF CARBON PACKING

Carbon packing rings in good condition show a uniform glazed surface on the inside diameter. Scoring observed on the shaft should be carefully smoothed, taking care to reduce the shaft diameter as little as possible. Carbon packing rings are designed to operate without lubrication and do not require any other than the natural lubricant contained in them. The presence of even the smallest amount of grease or oil in any form will prevent them from operating properly. Should the sealing surfaces of a packing housing become scratched or damaged, they should be restored by the use of a very smooth oil stone moistened with kerosene. When carbon packing is disassembled for inspection or renewal, special care must be taken to insure that the rings are installed in the proper grooves. Each segment is generally marked with the groove number in which it is assembled; usually the groove numbers are also stamped in the gland case. Where unvulcanized rubber dissolved in gasoline is used as gland joint compound, the gland should not be heated for an hour after assembly. However, the first time it is hot, the bolts should be tightened thoroughly. Care must be taken that none of the compound painted on gland case joint faces is permitted to get on any of the carbon rings.

50–31. FITTING CARBON PACKING RINGS

(1) Accurately fitting the joints and bores of carbon packing on turbine shafts is a difficult job which must be accomplished by hand after the original installation. A jig and gage as described herein (see Fig. 50–1) may be used to fit carbon rings to simplify such fitting and reduce the time required therefor. One size of each jig and gage is required for each bore of carbon rings. The jig can be made by using a square steel plate of a size approximately 1½ inches greater than the inside diameter of the carbon ring. The thickness should be approximately ⅜ inch greater than the width of the ring to be fitted. The upper part of the steel plate should be turned to a diameter of 0.001 inch to 0.002 inch less than the final bore required for the carbon ring. The width of the turned surface should be about ⅛ inch greater than the width of the carbon ring. The periphery of the turned surface should have marks scribed in a diagonal direction, approximately ½ inch pitch and deep enough to raise a cutting edge. A depth of 0.003 inch is considered sufficient. At the bottom of this turned surface add 1/16 inch radius

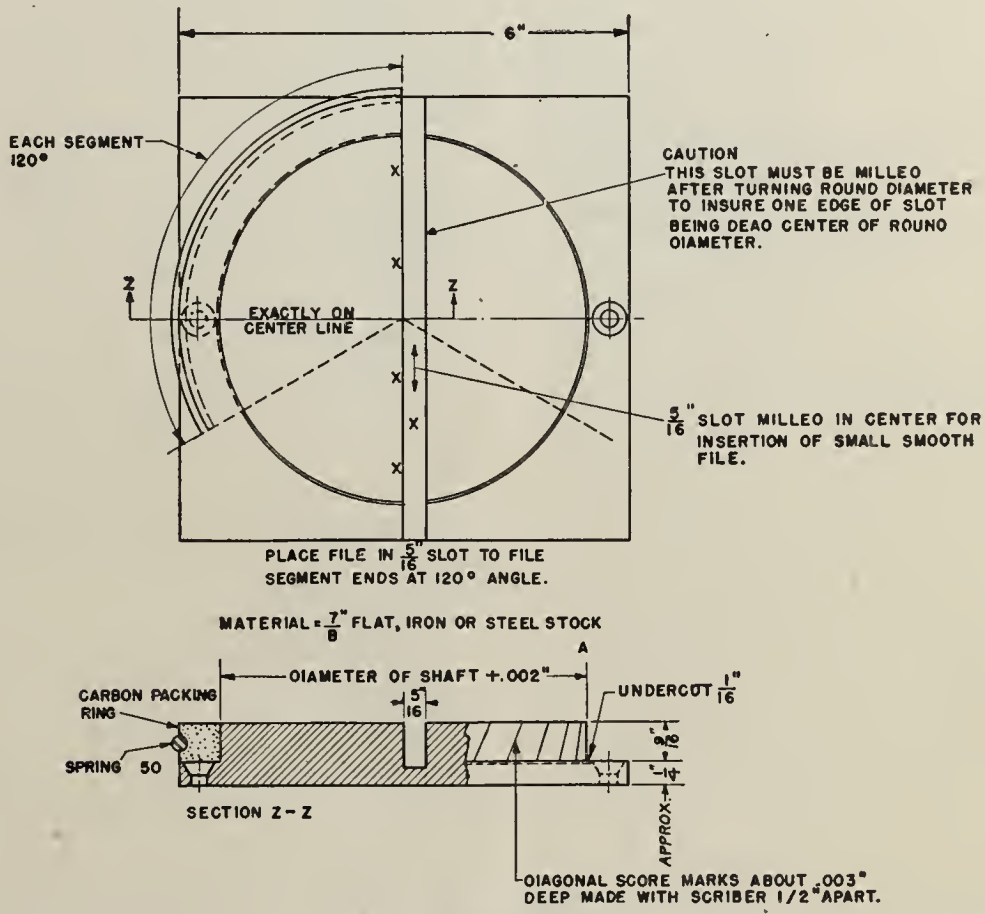
6"
EACH SEGMENT 120°
CAUTION THIS SLOT MUST BE MILLED AFTER TURNING ROUND DIAMETER TO INSURE ONE EDGE OF SLOT BEING DEAD CENTER OF ROUND DIAMETER.
EXACTLY ON CENTER LINE
5/16" SLOT MILLED IN CENTER FOR INSERTION OF SMALL SMOOTH FILE.
PLACE FILE IN 5/16" SLOT TO FILE SEGMENT ENDS AT 120° ANGLE.
MATERIAL = 7/8" FLAT, IRON OR STEEL STOCK
DIAMETER OF SHAFT +.002"
UNDERCUT 1/16"
CARBON PACKING RING
SPRING 50
SECTION Z-Z
APPROX.
DIAGONAL SCORE MARKS ABOUT .003" DEEP MADE WITH SCRIBER 1/2" APART.

FIGURE 50–1.

undercut in the adjacent surface to permit the corner of the carbon ring to bear properly on the turned surface. Cut a 7/16-inch slot completely through the fitting jig to a depth of 1/8 inch below the turned surface. One side of this slot must pass through the dead center of the turned surface and be true with it. Stamp an X on upper face adjacent to the side of the slot through the dead center and at each end of the slot remove all sharp edges from slot and edge of turned surface. Add two countersunk holes for wood screws in portion of steel plate which remains square for securing fitting jig to a board. The heads of wood screws should seat at least 1/32 inch below the surface.

(2) *Checking gage.* The checking gage can be made by turning a piece of steel to the same diameter as the shaft for which the carbon ring is to be used. The thickness should be 1/8 inch greater than the width of the ring. Drill and countersink for a wood screw through center. Both jig and gage can be fastened to a suitable board for convenience in handling and stowage and both parts may be lightened if desired by adding a bore through the center.

(3) *Method of fitting.* Assemble the carbon ring with its garter spring. Place on gage and check the fit of joints and the clearance between gage and ring with feelers. If the joints do not fit properly, or if the bore is too large, remove the ring from the gage, disassemble, and place each segment separately on the jig. Hold each segment securely in place and fit the joints with fine sandpaper wrapped on a flat file or block. The face of the slot which runs through the center of the fitting jig is used as a guide for this operation. It is necessary that the entire length of file or block be covered with sandpaper to avoid damage to the guide surface of the fitting jig when using a file and to prevent rocking. Remove sufficient carbon from the butts of segments to make the assembled ring too small to go over the gage. After each joint has been refitted the entire ring is reassembled with garter spring and placed on the fitting jig. The ring should be held against the bottom of the jig and turned by hand until the cutting edges of scribed marks have scraped out the bore sufficiently for the joints to butt. Remove the assembled ring from the jig and try on the gage. If too small, replace on the jig and scrape. If clearance is excessive, as checked by feelers, replace one segment on the jig and remove sufficient carbon from each butt to obtain the desired clearance. It is possible to make a jig and gage to suit more than one bore of ring by pyramiding one size on another.

(4) Some auxiliary steam turbines are fitted with rings which rub the shaft instead of having a clearance between the shaft and the ring as described above. For fitting rings on these units, the jig should be made so that its diameter, after scribing and including the height of the raised cutting edges, is the same as the shaft diameter. Rings cut on this jig should make contact with the shaft along the full length of each segment. Clearances should be provided between the butting ends of the segments. The total end clearance between the segments is usually about 0.006 inch. This clearance is provided by filing ends of the segments as described above in article 50-31 (3).

50-32. EXHAUST CASING PROTECTION AGAINST EXCESSIVE PRESSURE

(1) For protection of turbine exhaust casing against excessive pressure, a number of different devices are fitted on different turbines. These protective devices include sentinel valves, full relief valves, spring-loaded exhaust valves, steam and exhaust valve interlocks, and back pressure trips. On noncondensing turbines, sentinel valves should be set to lift at 8 p. s. i. above the normal designed back pressure; full relief valves should be set to lift at 10 p. s. i. above the normal designed back pressure. Spring-loaded exhaust valves should be set to lift at 2 p. s. i. gage, in excess of the normal designed auxiliary exhaust line pressure. For condensing turbines the settings of the various protective devices vary with different installations and the manufacturer's plans or instruction book should be consulted for the proper settings on any particular turbine. Turbines designed to operate noncondensing as well as condensing on the older ships in the Navy generally have the relief valves set to lift at 5 p. s. i. above the back pressure when operating noncondensing but not less than 20 p. s. i. gage. Back pressure trips, where used, are set at 5 p. s. i. above the relief valve setting. Where generator turbines are not fitted with connections for exhausting to the atmosphere, the relief valve is set at 5 p. s. i. gage and the back pressure trip is set at 10 p. s. i. gage. Back pressure trips are generally not provided on the older vessels where the generator turbines have individual condensers without gage valves in the turbine exhaust.

(2) All noncondensing turbines now in use should have:

(*a*) Relief valves with bores at least 1/2 inch larger than the steam inlet bore.

(*b*) Spring-loaded exhaust valves that can be held open but cannot be positively closed by hand.

(3) All condensing turbines now in use should have:

(*a*) Relief valve large enough to prevent the pressure in the condenser from exceeding 30 p. s. i. gage with throttle open or,

(*b*) Back pressure trip.

(4) The small relief valves on turbines are installed to act as sentinel valves to warn of undue increase in back pressure. They are not designed to relieve the turbine completely of excessive pressures, and when a sentinel valve "pops," the cause of the increase in pressure must be immediately ascertained. If necessary, shut down the turbine.

(5) Relief valves are sometimes provided with a shroud which is installed to permit piping away the steam if the valve blows. The piping leading

away from this valve shall not be plugged, nor shall any valve be installed in this line.

(6) Where stop valves are installed in the turbine exhaust lines and full relief valves are not provided on the casing or on the exhaust line between the turbine and the first stop valve, the turbine throttle valve hand wheel should be marked, preferably by installing RED warning disks underneath the hand wheel stating, "DON'T OPEN WHILE EXHAUST VALVE IS CLOSED," and similarly the exhaust valve hand wheel should be marked: "DON'T CLOSE WHILE THROTTLE VALVE IS OPEN." In addition to the warning plates, which should be installed at once, the situation should be immediately brought to the attention of the Bureau of Ships in order that steps may be taken to provide proper relief valves and spring-loaded exhaust valves.

50-33. STEAM STRAINERS, LOW-OIL-PRESSURE ALARMS AND TRIPS

(1) In addition to the protective devices referred to in articles 50-26, 50-27 and 50-32, other safety fixtures are provided on turbines, including steam strainers, low-oil-presure alarm contactors and low-oil-pressure trips.

(2) A steam strainer is located in the steam line ahead of the governor valve to prevent foreign material from entering the turbine. The strainer is in the form of a basket made of wire mesh or perforated corrosion-resisting steel. The steam strainer should be examined and cleaned quarterly or oftener if extensive cruising has been done, or where dirt or scale has been found in the last cleaning.

(3) The low-oil-pressure alarm contactor is a device provided on most generator turbines in the lubricating oil system which completes an electric circuit to an audible alarm in case the oil pressure drops to the minimum for safe running.

(4) The low-oil-pressure trip is a device provided on some generator turbines and is connected to the lubricating oil system. This device operates in conjunction with the overspeed tripping mechanism and functions to shut down the turbine if the oil pressure drops below a predetermined minimum. Low-oil-pressure trips are generally provided on generator turbines which are equipped with a governing system that will not shut down the turbine in case of loss of oil pressure. Low-oil-pressure alarm contactors are generally not provided on turbines which are equipped with low-oil-pressure trips. The plans or manufacturer's instruction book should be consulted for the correct setting of a low-oil-pressure alarm contactor or low-oil-pressure trip on any particular turbine. These devices are usually set to operate at about 4 p. s. i. gage. Where both protective devices are installed, the alarm is set 2 to 3 p. s. i. above the trip. When a low-oil-pressure trip or alarm contactor operates, the trouble should be located and corrected immediately. (See art. 50-15.)

50-34. VACUUM

The economy of operation of condensing turbines depends upon the vacuum maintained; therefore packing and joints must be kept in condition to prevent all leaks. A high vacuum once attained can be maintained easily and permanently by taking the following precautions:

(*a*) Keep gland packing in good condition and keep feather of steam coming from steam-packed glands at all times.

(*b*) Insure that there are no air leaks in condenser, exhaust trunks, lines to air pumps, etc. To insure tightness, joints of all lines under vacuum of dynamo condenser shall be painted with shellac, asphaltum paint, or litharge at least once a quarter; the painting to be done while there is a vacuum of at least 20 inches of mercury on the condenser.

(*c*) Keep air pumps and ejectors in excellent condition.

(*d*) Run air pumps at the slowest speed that will maintain the vacuum.

50-35. MAKING TURBINE CASING JOINTS

(1) Extreme care must be taken in making a turbine-casing joint. The joint surfaces should be carefully scraped and cleaned, then polished with crocus cloth. The joint faces should be carefully inspected for burrs and bruises. Never use sheet gasket material when remaking a steam casing joint.

(2) To make the joint of a turbine, coat the surfaces with a thin layer of linseed oil and graphite, manganesite, Copaltite, or ½ inch strips of $\frac{1}{32}$ inch thick Usudurian packing inside the bolt circle. Opposite bolts should be set up fairly tight and then followed around until all are firmly secured. Gland joints are to be made in the same manner. For a complete description of making turbine casing joints, see chapter 41.

50-36. GROOVING OF JOINTS

A simple system of joint grooving is provided on some generator turbines, together with arrangements for pressure pumping grooves with an approved form of steam sealing compound. However, grooves shall not be so pumped except when absolutely necessary in effecting emergency repairs in service. It shall not be used during routine overhaul unless flange surfaces are in poor condition and time or facilities are insufficient for resurfacing. Sealing grooves should be pumped with a compound conforming to the requirements of Bureau of Ships Specification 52C14, using a pressure pumping outfit furnished with the ship's tools. Two commonly used compounds are Furmanite and Copaltite. The use of Furmanite is restricted to temperatures not exceeding 425° F. Copaltite is satisfactory for temperatures up to 850° F. When pumping sealing grooves, start at one end of the groove, remove all pipe plugs from holes connecting sealing grooves, pump the end hole until sealing compound shows at the second connecting hole, insert plug and pump until compound

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shows at the next connecting hole. Continue this sequence until all holes have been filled.

50-37. ROTOR CLEARANCES

(1) Axial flow turbines are generally provided with an opening in the casing for the purpose of inspecting the blade clearance. Tapered gages are inserted between the nozzle face and shroud band of first row of blades for measurement of axial clearance. If the clearance is found to be outside the limits prescribed by the manufacturer, the position of the rotor should be adjusted accordingly. After adjusting the clearance, rotate the rotor by hand to be sure there is no rubbing.

(2) Turbine rotors having integral buckets of the Sturtevant and Terry helical flow type must always be kept in axial alignment with the nozzles and reversing chambers, otherwise the steam will spill over the edges or rim of the wheel and reversing chambers resulting in reduced economy and power. Manufacturers' instructions as to alignment should be followed.

50-38. REPAIR OF BLADES

When turbine casing is opened, all blades should be examined. If any are bent, they should be straightened, care being taken to insure that in straightening, blades are not cracked. A cracked blade may come adrift; therefore, it should be cut out flush with the disk, leaving the blade root in place, or the row should be rebladed to avoid a turbine casualty. When a cracked blade is cut out, the blade diametrically opposite shall be cut out also in order to keep the rotor in balance.

50-39. REDUCTION GEARS

(1) A turbine operates economically at a high speed whereas in some cases, the driven auxiliary is most efficient when operating at a low speed. To derive efficient results, each unit must operate at its approximate economical speed. To effect this requirement mechanical reduction gears are used. Reduction gears used with auxiliary turbines are of two types, namely, helical and worm. Helical gears are employed where the shaft of the driven auxiliary is mounted parallel to the shaft of the turbine. Worm gears are employed where the shaft of the driven auxiliary is mounted perpendicular to the shaft of the turbine. If the gears are aligned properly and satisfactory tooth contact is obtained when gears are first installed, little trouble should be experienced with auxiliary turbine reduction gears provided they are supplied with an ample quantity of clean lubricating oil.

(2) New gears, or gears which have been realigned, should be thoroughly worn in at low power before being subjected to the maximum tooth pressure of full power. Pitting, particularly along the pitch line, may occur in the first few weeks of service. This pitting usually ceases after this time and no further trouble is experienced. The only care necessary is to see that no flakes of metal are allowed to remain in the oiling system. Operation of the gears is not otherwise affected by the slight pitting.

(3) A properly operating gear has a certain definite sound, which the trained operator can easily recognize. The cause of any unusual noises should be investigated and the unit should be operated with caution until the cause is discovered and remedied. Vibration is caused by faulty alignment, bent shafts, damaged driven auxiliary, etc., or by improper balance. Gear wheels, pinions, and worms are balanced dynamically when the units are built. Unless damaged or corroded in service, or improperly erected, they should remain in balance. Indications of unbalance in the gear are manifested in unusual vibration and noise and unusual wear of bearings. The vibration may, however, be due to unbalance in the turbine or in the driven auxiliary. The turbine rotor is much more likely to be out of balance than the gears.

(4) The amount of wear of gear bearings shall not be allowed to become sufficiently great to cause incorrect tooth contact. (See Article 50-18 for rebabbitting of bearings.) It is essential, for proper operation of the gears, that the total tooth pressure be uniformly distributed over the total length of the tooth faces. This is accomplished by accurate alignment and adherence to the designed clearances. The designed center to center distance of the axes of the rotating elements should be maintained as close as practicable and in all helical gears the axes of pinion and gear shafts must be parallel. Nonparallel shafts concentrate the load on one end of a helix and may cause a feather edge on teeth, flaking, galling, pitting, or deformation of tooth contour or may break the ends of teeth.

(5) All gears are fitted with spray nozzles which spray oil on the meshing teeth. These spray nozzles shall be kept open at all times. No oil-spray apparatus, fitted for lubrication of gears, shall be altered or rendered inoperative without authority of the Bureau.

(6) Proper initial alignment, an adequate supply of lubricating oil at all times, proper clearances, and inspection for damages should prevent trouble from wearing and scoring of teeth. If, after all precautions, the lubricating oil supply should fail and the teeth become scored, the gears must be overhauled at the first opportunity.

(7) The teeth should never be dressed as long as the gear is operating satisfactorily, not even in case of excessive abrasion, until after every attempt has been made to rectify the alignment. The abraded portions of the teeth should be dressed only sufficiently to prevent scoring of meshing teeth. Steel scrapers or a fine file should be used and every precaution taken to remove all emery, filings, or abrasive material. No attempt should be made to remove deep pitting or galling. In the case of helical gears where both pinion and gear teeth have been damaged by foreign bodies, both should be relieved

of all humps. Further spotting and scraping should be confined to the teeth of the gear wheel. The high spots will show more quickly on the pinion because they come in contact oftener.

(8) The instruction book for any particular installation will usually prescribe method and equipment for determining the alignment of gears. In service the best indication of proper alignment is good tooth contact and quiet operation.

(9) Tooth contact can best be checked by treating the pinion teeth with a light coating of metal marking, preferably Prussian blue, red lead, or copper sulphate, and rotating the pinion in mesh with the gear. Observe the tooth contact and, if necessary, make adjustments to obtain proper tooth contact. For helical gears 80 percent of the face width should make contact; the contact should be uniformly distributed along the entire face width of the tooth. Necessary adjustments may include rebabbitting or renewal of bearings or scraping of teeth. The scraping process is only useful to remove a local high spot or deformation. General scraping of teeth shall be avoided, as this is likely to make matters worse instead of better.

(10) Gear cases are sometimes provided with inspection plates so that rotating parts may be sighted. Tooth contact and condition of teeth should be examined at periodic intervals at the discretion of the engineer officer. Before inspection covers are removed, the vicinity of the opening must be free of all nuts, bolts, tools, or other foreign matter that might fall into the gear case and cause damage. While gear cases are open, the openings shall never be left unattended unless satisfactory temporary closures have been installed. Before replacing an inspection plate, connection, fitting, or cover which permits access to the gear casing, a careful inspection shall be made by a responsible officer to insure that no foreign matter has entered, or remains in the casing.

50-40. STEAM EXTRACTION

(1) Some generator turbines on older vessels are provided with a connection for bleeding steam into the auxiliary exhaust line. Such a connection is not fitted on recent vessels as the auxiliary exhaust is augmented from the auxiliary steam line via reducing valves. On many of the older vessels this bleeder outlet has been blanked off. This extraction connection is generally located in the first stage chamber of the turbine. The pressure regulating valve, pilot valve, and stop and nonreturn valve comprising the steam-extraction control equipment should be maintained and inspected in accordance with chapter 48.

(2) In the case of generator turbines of small capacity, a heavy extraction demand occurring when the unit is operating on light load might rob the subsequent stages of nearly all steam flow thus reducing the stage pressure below the extraction pressure and automatically limiting the amount extracted, if no means were provided to prevent this condition. To obviate this condition, a device is provided to close off some of the second stage diaphragm nozzles and thereby build up the pressure in the extraction stage to the desired extraction pressure. In General Electric turbines this device consists of a manually-operated slide valve or sector. In Westinghouse turbines some of the second stage diaphragm nozzles are partitioned off and connected to the Curtis wheel chamber by a separate passage controlled by a hand-controlled bypass valve. The slide valve or bypass valve should be adjusted to give the desired pressure on the extraction stage when extracting steam. When operating straight condensing, the slide valve or bypass valve should be fully open at all loads.

50-41. GOVERNOR VALVE SEATS

(1) When turbines are dismantled for repairs or inspection, the condition of the governor valve seats should be checked. Where governor valve seats are found to be loose, they should be seal welded or silver soldered in place, if practicable. Also inspection of valve seats frequently discloses that seating areas are steam cut and eroded. When replacement valve seats are ordered, unless the plans already call for such, specify that the seating areas are to be faced with chromium-cobalt alloy.

(2) Loose governor valve seats on generator turbines may be caused by too sudden changes in steam temperature, since some generator turbines operate on saturated steam when in port and superheated steam when at sea. The sudden change in temperature might occur from not shifting the turbine to the superheated line until after the ship is well under way and the main steam temperature has reached well into the superheat range; or it might be caused by sudden drops of steam temperature in the line due to carry over of feed water. The change from saturated to superheated steam should be made at the time the propulsion turbines are being prepared for getting under way, and not after the ship has gone to sea and the steam temperature brought up to normal. Also, when shifting from the superheated to the saturated header, the change should be made at the time the propulsion turbines are being secured and the superheat temperature has been gradually reduced to about the saturated temperature. When starting a turbine, sufficient time should be taken to heat the steam chest gradually, keeping the rotor turning slowly, rather than to put full steam into the unit suddenly before such warming up can occur. In case of emergency, a quick start may be necessary but this method of starting should be avoided whenever practicable.

50-42. ACCUMULATION OF DEFECTS

Defects such as pitting of ball races, excessive clearance in bearings, excessive clearance between steam nozzles and rotors or misalignment of same, oil relief valve and oil system clogged with dirt, leaky valves, excessive wear in oil pumps, leaky packing, etc., should not be allowed to accumulate.

Such accumulation is preventable by systematic inspection, test, checking of clearance, and periodic overhaul, together with proper operating procedure.

50–43. VIBRATION

(1) Vibration in a turbine is a positive indication that the unit is not in proper working condition, and as soon as this condition is noted, a thorough investigation should be made to determine the cause of the trouble. If the trouble is not immediately remedied and defects are allowed to accumulate, bearing and packing clearances become excessive, with consequent loss of oil and steam; the bearings and packing are soon ruined and if the turbine is kept in operation, further trouble may develop resulting in complete disablement of the unit.

(2) Vibration of a unit may be caused by—

(*a*) Loose or poorly lubricated bearings.

(*b*) Worn thrust bearings.

(*c*) Parts rubbing or binding.

(*d*) Driven unit out of balance.

(*e*) Driven unit out of alignment.

(*f*) Turbine rotor out of balance.

(*g*) Loose or broken foundation bolts.

(*h*) Carbon packing clearances too small.

(*i*) Bent shaft.

(3) Should a turbine vibrate to such an extent that an out-of-balance condition is suspected, the following steps should be taken:

(*a*) Examine bearings and renew if it is found that the clearance is excessive.

(*b*) Examine and if necessary adjust or renew the thrust bearing.

(*c*) Examine all parts for evidence of rubbing or binding.

(*d*) See if carbon packing clearances are satisfactory. If clearances are too small, the vibration will get worse if speed and temperature are kept constant; also, the shaft will overheat due to friction and start to show heating colors. Be sure that sufficient steam is being supplied to gland. Refit packing if necessary.

(*e*) Check alignment.

(*f*) Look for loose bolts in the unit and its support. Replace or tighten any that are found.

(*g*) Remove rotor and shaft, and check shaft in lathe for runout.

(*h*) After above steps have been taken and turbine is reassembled, run the unit at normal speed to determine if the vibration has been eliminated.

(*i*) If the turbine still vibrates, it may be assumed that it is still out of balance and a running balance must be made. This may be accomplished in place by use of the Davey vibrometer carried by tenders and repair ships, or by removal from the vessel and balancing at a naval shipyard. If Davey vibrometer is used, maximum readings on vibrometer scale should not exceed 0.003 inch.

50–44. CARE AND INSPECTION

(1) After each period of steaming, and in any case at least once a quarter, the turbine foundation and the unit itself shall be carefully inspected for loose or broken nuts or bolts. If any are found, they shall be renewed or tightened immediately.

(2) Concurrently with the above examination, care shall be exercised to inspect the turbine casing interior, especially near glands and in all locations where water may collect in pockets or under the lagging. Experience has shown that where water or dampness is permitted to remain in contact with the casings, the casings may be seriously weakened by corrosion before the situation is discovered. Where drain holes are provided in pockets, these holes must be kept open, and they should be of such size that they are not easily stopped up. Where indications of active corrosion are discovered, the affected surfaces should be properly bared and cleaned to good metal, removing lagging where required to accomplish this. Then the exposed surface should be dried and painted with two coats of approved paint. Lagging should then be replaced and such steps as may be practicable should be taken to prevent recurrence.

(3) All sliding contacts and pivot points in governor and overspeed tripping mechanisms shall be kept free, clean, and well oiled in order that there will be no sticking which will prevent the safety devices from functioning at the set speed of rotation. Particular attention shall be given to the condition of split pins or other securing devices on overspeed tripping mechanisms.

(4) When a turbine is new or after extensive repairs have been made to a unit, renew or renovate the oil in the reservoir frequently. At other times renew the oil or run it through the purifier often enough to insure that it is perfectly clean. When considered necessary, flush out the system by running the turbine slowly for several minutes with an approved flushing oil in the system in order to clean out thoroughly all lines, bearings, pockets, etc. Then drain off the flushing compound and fill reservoir with clean oil.

50–45. ALIGNMENT OF TURBINE WITH DRIVEN UNIT

(1) The most important alignment in a horizontal turbine relates to the coupling between the turbine and the driven apparatus. The shafts of the two must be in correct alignment. Therefore, it is very important to determine that the face and sides of the coupling run parallel and true to each other.

(2) The preliminary alignment is usually made when the apparatus is cold and before piping is connected. It should be borne in mind that the turbine center line may or may not rise when steam is turned on depending upon the direction of rotation; that is, whether the pinion teeth push down or lift up in rotating the bull gear. For this reason the manufacturer's plans and instruction book should always be consulted for alignment data. The final alignment should be made after the turbine is connected to the piping. The final alignment should be such

that the coupling will not run out; otherwise, vibration will result and the bearings will wear rapidly.

50–46. BRIDGE GAGES

(1) Bridge gages for measuring bearing wear are required equipment on generator turbines of 600 kilowatts and above. The clearance when the journal is in its proper position is stamped on the bridge gage; the difference between the reading as measured and that stamped on the gage represents the wear in the bearing. The thickness of oil film between the journal and its bearing will affect the reading. For this reason, if practicable, bridge gage readings should be taken after the unit has been shut down for a period of 24 hours. If impracticable to wait 24 hours after shutting down the unit, the interval between shutting down the unit and taking the readings should be made as long as possible.

(2) As bridge gages will not show bearing wear if the reaction is against the bearing cap, a more accurate method consists of measuring the thickness of the bearing shell at the point of reaction or wear. This "crown thickness" may be recorded when the unit is known to be in proper alignment. If radial lines are scribed on the end of a shell and the original crown thickness is stenciled adjacent thereto, much time will be saved checking subsequent wear, and rebabbitting and boring; this also eliminates any question as to whether or not the bridge gages have warped or been damaged.

(3) Bridge gage or crown thickness readings should be carefully taken at periodic intervals and a permanent record kept of all readings taken. On larger units, turbine bearings are fitted with bearing wear micrometers. The micrometer readings are intended as a check of operating conditions between overhaul periods. The bridge gages should always be used during regular overhauls unless upper and lower shells have been stenciled with the crown thickness constants.

(4) Before using a bridge gage, it must be determined that it has not been deformed in any way. The contact surfaces of both the gage and the bearing housing, as well as the points where the measurements are taken, must be free of all dirt, grease, burrs, or other foreign matter. Some turbines are supplied with bridge gages which are provided with pin gages or templates to check for possible distortion of bridge gages. Where such pins or templates are provided, they should be employed before bridge gage readings are taken.

50–47. SAFETY PRECAUTIONS

(1) Turn turbine by hand daily and before admitting steam to casing.

(2) Do not lash down an overspeed trip nor a speed-limiting governor, nor take other steps to render them inoperative.

(3) Keep the exhaust casing relief valve set at the proper pressure and in operating condition at all times. Test by hand before admitting steam to casing, and test quarterly by steam by gradually closing the exhaust valve if fitted until relief valve lifts. An exhaust pressure gage must be carefully watched during this testing.

(4) Keep the oil reservoir well filled with clean oil at all times.

(5) Before starting turbine inspect to see that it is clear of foreign matter, especially if the unit has not been operated for a long period.

(6) Keep the unit properly balanced at all times.

(7) Avoid water hammer by properly draining lines and opening valves slowly.

(8) Before turbine is put in service, test the overspeed trip, if provided.

(9) Test the speed-limiting governor by steam at least once a quarter.

(10) Avoid passing steam through a turbine with the rotor at rest.

(11) Avoid air being drawn through generator turbine glands with the rotor at rest.

(12) Keep the governor operating mechanism and regulating valve stems clean and free from corrosion and the cylinder insulation well clear of the steam-chest lift rods.

(13) Keep bearing oil pressure at the proper amount.

(14) Keep the oil strainer clean.

(15) Keep the oil cooler clean.

(16) Numerous turbo-generators have been damaged in the past due to the carry-over of slugs of water in the steam when starting up generators in emergencies before steam lines could be properly drained. Such casualties can be avoided if a stand-by generator is selected ahead of time and the line to this unit is kept warmed up and drained during periods that might require quick cut-in of the stand-by unit.

50–48. INSPECTION AND ROUTINE

(1) The following inspections and routine shall be carried out while the ship is underway:

When made	Part of system	Purpose
(*a*) At very short intervals during each watch	Bearings	To detect signs of overheating.
(*b*) At very short intervals during each watch	Flow of oil made through sight glasses	To check flow of oil.
(*c*) At very short intervals during each watch	Rotor position indicator on generator sets	To check axial position of rotor.
(*d*) At very short intervals during each watch	All gages	To check pressures.
(*e*) Once a watch	Ball thrust bearing and radial bearings	Listen to detect defects in or damage to bearings.
(*f*) Once a watch	Operate speed-limiting or speed-regulating valve stem manually.	To insure proper functioning. Caution: Do not overspeed unit.
(*g*) Daily	Parts under vacuum	For air leaks.

(2) The following inspections and routine shall be carried out at anchor, and appropriate entries shall be made in the log:

When made	Part of installation	Purpose
(*a*) Daily	Turn idle turbines by hand and circulate oil by hand pump, if provided.	To prevent freezing.
(*b*) Weekly	Valves, cocks, joints of steam, exhaust and drain lines	For tightness.
(*c*) Weekly	Operate and oil the regulating valves and throttle valves.	To prevent sticking.
(*d*) Weekly	Operate and oil, if possible, all valves not used	To prevent freezing of parts.
(*e*) Weekly	Lubricate the overspeed trip mechanism, if installed	To prevent sticking.
(*f*) Weekly	Run the turbine with steam if practicable	To assure that turbine will be ready on short notice.
(*g*) Weekly	Test the overspeed trip, if installed, by overspeeding the unit (see article 50-28).	To prevent freezing of parts.
(*h*) Weekly	Operate relief valves by hand	To prevent sticking.
(*i*) Quarterly	Test speed-limiting governor as laid down in article 50-28. (This shall also be done each time a turbine is put in operation after having been permanently secured.)	To see that governor functions at speeds for which set.
(*j*) Quarterly	Examine casing interior through peep holes where design permits.	To see that rotor and nozzles are in line.
(*k*) Quarterly	Sound the casing with a hammer	To detect cracks.
(*l*) Quarterly	Examine for loose or broken bolts, inspect turbine casing exterior for corrosion.	To detect signs of loosening of turbine fastening and to detect corrosion.
(*m*) Quarterly	Test relief valve by steam	To check proper setting.
(*n*) Quarterly	Clean the steam strainers (clean oftener if extensive cruising has been done).	To prevent foreign matter from entering turbine and to insure integrity of the strainers
(*o*) Quarterly	Shoes of thrust for clearance and condition of bearing surface.	To insure proper position of rotor.
(*p*) Quarterly	Blow out thrust with air after examination	To prevent foreign matter remaining.
(*q*) Quarterly	Sleeve bearings for clearance, condition of journal and bearing surfaces.	To insure that radial clearance is correct.
(*r*) Quarterly	Calibrate gages	To insure correct readings.
(*s*) Biannually	Gland packing for wear	To insure maintenance of efficient seal.
(*t*) Biannually	Open up and examine all ball bearings and radial bearings	For examination and cleaning.
(*u*) When first starting turbine (cold)	Rotor position indicator on generator turbines	To check axial clearances.
(*v*) When first starting turbine (hot)	Rotor position indicator on generator turbines	To check axial clearances.

50–49. MACHINERY HISTORY

It is of great importance that the machinery history contain a complete record of the turbine installation from time of commissioning. Prospective engineer officers of the building yard should provide the first machinery history card for each unit with complete manufacturer's data regarding the installation. This should include the original rotor clearances, bearing clearances, thrust settings and clearances, bridge gage or crown thickness readings or alignment gage readings for gears, and tooth clearances (backlash and root) of the gear and pinion. For overhaul or repair purposes it is essential that the original data be at hand. An accurate record of all repairs, adjustments, readings, and casualties shall be kept in the machinery history.

50–50. REPAIRS

A sample repair guide list which should be followed in the overhaul of a turbine is given below:

No _____ Turbine
Type _____
Manufacturer _____
Size _____
Date _____

	Done	Not done
1. Assemble drawings		
2. Collect previous data		
3. Sleeve bearings		
(*a*) Take bridge gage or crown thickness reading		

	Standard	Present bridge gage reading or crown thickness	Last bridge gage reading or crown thickness	Amount of wear	Done	Not done
Turbine bearing, for'd						
Turbine bearing, aft						
Pinion bearing, for'd						
Pinion bearing, aft						
Gear bearing, for'd						
Gear bearing, aft						

	Done	Not done
(*b*) Inspect, clean, rebabbitt or renew		
(*c*) Clean and dress journal		
(*d*) Clean oil wells, passages, pockets, etc		
(*e*) Reassemble		
4. Thrust bearing:		
(*a*) Inspect, clean, renew parts:		
1. Ball bearings		
2. Collar		
3. Shoes or thrust plates		
(*b*) Adjust for proper clearance		

	Done	Not done
5. Turbine valves:		
(a) Examine		
(b) Adjust		
(c) Grind in seat		
(d) Grind in disk		
(e) Test		
6. Fittings:		
(a) Inspect, clean, and adjust:		
1. Relief valve		
2. Speed-limiting or constant-speed governor		
3. Overspeed trip		
4. Low-oil pressure alarm contactor or trip		
5. Back pressure trip		
6. Gages		
7. Packing:		
(a) Examine for defective segments or rings		
(b) Clean all parts		
(c) Replace defective parts		
(d) Adjust and reassemble		
8. Rotor:		
(a) Inspect:		
1. Blade wheels		
2. Keys for blade wheels		
3. Wheel securing nuts		
4. Blades		
5. Shrouding		
6. Packing sleeves		
7. Forward journal		
8. After journal		
(b) Clean all parts		
(c) Straighten blades		
(d) Clean, polish, straighten shaft		
(e) Measure and record axial clearances		
(f) Adjust axial clearance		
9. Casing:		
(a) Inspect and clean as necessary:		
1. Interior surface of casing		
2. Nozzle		
3. Nozzle diaphragms		
4. Diaphragm packing rings		
5. Axial crushing pins		
6. Radial crushing pins		
(b) Examine for loose nozzle bolts or nuts and tighten if found		
(c) Clear all drain holes		

	Done	Not done
10. Oil system:		
(a) Inspect, clean, adjust:		
1. Lines		
2. Reservoir		
3. Strainer		
4. Oil pump		
5. Oil gage		
6. Hydraulic cylinders		
7. Oil cooler		
(b) Flush with approved compound		
(c) Flush with oil		
(d) Refill with clean oil		
11. Replacing casing:		
(a) Clean flanges, bolt holes, etc		
(b) Clear grooves		
(c) Polish flanges		
(d) Examine casing for articles left behind (tools, waste, metal, etc.)		
(e) Blow through with air		
(f) Apply jointing material		
(g) Lower cover		
(h) Replace bolts and set up on nuts		
12. Reduction gears:		
(a) Thoroughly clean by blowing with air:		
1. All oil passages in the casing		
2. Oil pipes		
3. Oil manifolds		
4. Spray nozzles		
(b) Examine pinions and gears for:		
1. Damaged teeth		
2. Pitting		
3. Rusting		
(c) Remove any burrs from pinion or gear with a fine file or oilstone		
(d) Check alignment and clearances		
(e) Clean oil joints of casing		
(f) See that no material is left in gear case		
(g) Replace covers		
13. Reassemble:		
(a) Check alignment of turbine and driven apparatus		
(b) Check alignment of rotating blades and stationary blades or reversing chambers		
14. Test:		
(a) Turn over by hand		
(b) Turn over with steam		
(c) Test overspeed trip or speed-limiting governor		

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